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The Pennsylvania State College
The Graduate School
Department of Agricultural and Biological Chemistry

A Chemical Study of the Fertility of Certain
Lancaster County Tobacco Soils

A Thesis

by

William Lyon Porter

Submitted in partial fulfillment
for the degree of
Master of Science

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May 11 1938

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I. Introduction

The tobacco plant has, for many years, played an important role in the economic agriculture of Lancaster County. Although a number of crop plants grown in this locality may be grown equally well elsewhere, this certainly does not hold true for tobacco. The type of tobacco grown in the county is a direct result of its environment. Since this is true, it is questionable whether it is possible to extend this particular area and at the same time preserve the characteristics of the quality of the product which has been demanded by the cigar smoking public. However, there is plenty of opportunity for a continued improvement and development of the area now in use, and further improvement of the quality should enhance the consumption of the final product and in turn increase the demand for the tobacco for manufacturing purposes.

In the course of previous research many and varied problems have been uncovered. Control of insects harmful to tobacco, bacterial and fungus diseases, and so on, are under consideration. The mineral constitution of the plant has been under surveillance for several years. For a long period of time, its fertilizer treatment has been under consideration by both chemists and agronomists. However, only total analyses and base-exchange results have been recorded thus far. These nutrients being insoluble are

available for plant growth only if the plant roots effect intimate contact with the soil particles; replacement being effected by the hydrogen of carbonic acid liberated through the root system. Since these constitute the main supply of mineral nutrients for plant growth, the ease of replacement or their ready availability should be considered.

Considering the above statements, it has been thought advisable to investigate a means for determining the concentration of nutrients in the soil for the production of a crop having the best quality. This investigation involves, primarily, a study of the availabilities of the several plant nutrients by means of rapid soil tests, the final result to be a set of standards to be used for the recommendation of fertilizer combinations.

II. Object of these Investigations

The object of these investigations is: first, to study the availability of nitrogen, phosphoric acid, potash, and calcium in a number of average tobacco soils before and after the usual fertilizer treatment; second, to fix rather definite standards of fertilizer treatment from these data.

III. Results of Previous Investigations

For many years, investigations into the fertility of soil have been carried on. The focus of interest has changed many times as results of the work have been correlated.

The first method of attack, from a chemical standpoint, seems to have been the determination of the elemental composition of the soil. This line of attack had its limitations, since for the most part the elements are in forms which are not available for plant growth. This, however, does in no way discount the importance of a knowledge of the elemental composition of the soil, since these data have aided in determining that the infertility of certain soils may be attributed to the presence of a certain element such as selenium or to the absence of an element essential to plant growth, such as zinc. Regarding forms of combination in which soil elements occur, spectroscopic and mineral analyses have been utilized.

While the elements in mineral form are not available for plant growth to any appreciable extent, the complexes which arise from the weathering processes play an important role. These complexes are colloidal in nature and contain hydrogen which appears to be readily replaced by bases and in this way are held against the forces of leaching.

Although insoluble, these are available for plants if the plant roots effect intimate contact with the soil particle; replacement is effected by the hydrogen of carbonic acid liberated through the root system.

Much attention has been given to these so-called inorganic "base-exchange" complexes. We know how they are built up or torn down and we are beginning to appreciate how these may affect the "physiological balance" of the mineral nutrients for plant growth. While many reagents have been used to remove the replaceable bases under laboratory conditions, the preferable one seems to be normal ammonium acetate adjusted to pH 6.8.

While the elements found in replaceable form constitute the main supply of mineral nutrients for plant growth, the ease of displacement and therefore their ready availability is the next phase to be considered (8).

Numerous solvents and methods for extracting the available portions of the mineral nutrients of soils have been suggested by investigations in this field. Carbonated water as a solvent was proposed by Gerlach (5) and Schloesing (19). Humic acid was tried by Hofmeister (9). Maxwell (14) used and recommended one per cent aspartic acid.

In 1894, Dyer (2) proposed the use of one per cent citric acid as a leaching agent in the determination of available potassium. He correlated the amounts of citric acid-soluble

elements with actual crop yields on Rothamsted soils which had received the same fertilizer treatment for many years. In 1901 (3), this work was further substantiated when he found that yields of barley could be very closely correlated with the amounts of potassium dissolved by citric acid.

Hall and Plymen (7), in 1902, using one per cent citric acid, one per cent acetic acid, and 0.04 normal carbonic acid reported that citric acid gave the most favorable comparison between soluble potassium and soil productivity. A year later Hall and Amos (6) tried the effect of repeated extractions with the above solvents and because of the deflocculation brought about by the acetic acid and the carbonic acid, they finally used citric acid only. This work brought out the fact that a single extraction gave as much information as repeated treatments with the same solvent.

In 1923, Konig, Hasenbaumer, and Schaefers (10) compared the available supply of mineral nutrients, as determined by citric acid extraction, with extraction by steaming for a five-hour period. They were able to get high correlation between the treatments and also the steam extraction could be correlated with the amounts of potassium removed by the potato crop. Liebscher has been quoted as having used ten per cent hydrochloric acid as a solvent.

Neubauer (17)(18) departed from the rapid testing system by devising a biological test consisting of growing rye seed-

lings in the soil and measuring the amount of nutrients absorbed by the seedlings over a period of eighteen days.

McGeorge (12) (13) used several solvents including one per cent citric acid and 0.2 normal nitric acid and with Hawaiian soils found that the best indication was given by citric acid.

Fischer (4) has pointed out the importance of the presence of other cations, especially calcium, upon the availability of potassium and its use by plants. The utilization of plants as indicators of potassium deficiency in soils is no doubt influenced by these considerations. This relationship may be important in making comparisons of the potassium that plants can absorb from different soils.

In 1933, Spurway (21) published a soil testing method which involved the use of one part acetic acid to three parts of water. A year later Thornton, Conner, and Fraser (22) reported the use of several extracting agents. A mixture of ammonium molybdate and hydrochloric acid was used for the determination of phosphoric acid and a mixture of sodium cobaltinitrite, sodium nitrite, and acetic acid was used for potassium.

In 1935, Morgan (16) published his "Universal Soil Testing System" in which he used a 0.5 normal solution of sodium acetate adjusted to pH 4.8. Using this system, he drew up a set of fertilizer recommendations for many different

crop plants.

Merkle (15) has perfected a system in which a 0.25 normal sodium acetate solution adjusted to pH 5.0 is used. His system seemed to meet our demands to a greater extent than did Morgan's; hence, it was utilized in this investigation.

IV. Plan of the Experiment

A. Description of the samples used

The soils used in these investigations were collected from the various sulfur plots and the three-year rotation plots at the Roseville Tobacco Experiment Station about two miles north of Lancaster, Pennsylvania. Other samples were collected over widely separated portions of Lancaster County.

The three-year rotation samples are from fertilizer plots that have had the same treatment for some years. The sulfur plots have had the same treatments for four years. The outlying samples were from farms well distributed over the county. Most of these were from fertile farms but some were not so fertile.

An auger, $1\frac{3}{4}$ inches in diameter, was used to sample to a depth of 6 inches. Enough borings were taken in the row between plants over half an acre to give about one quart of soil. The soils were then air dried and prepared for analysis. The sample was ground to 20 mesh and the stones, pebbles, and roots were discarded. This was quartered, one quarter being ground to 100 mesh for analysis and the other three quarters stored for future reference. All samples were treated as nearly alike as was possible under the circumstances.

The three-year rotation plots are divided into three tiers, each tier having thirty-one sections. The corresponding section in each tier receives the same treatment. Tier II was used for tobacco in 1936 and Tier III was planted with the same crop in 1937. These treatments are recorded in Table I.

The sulfur plots were set up in order to show the effect of acidity on the production of Pennsylvania Cigar-Leaf Tobacco. These plots are also divided into three tiers, each tier having six sections. Each tier received a different fertilizer formula but to the corresponding sections was added the same amount of sulfur. The sulfur and fertilizer treatments of these plots are given in Table II.

Table I

The field treatments of the experimental plots,
Tiers I, II and III of the three-year rotation system.
All figures are given on the basis of one acre.

Plot Number	Manure Tons	Fertilizer Pounds	Formula	Lime Pounds	Fertilizer Applied
1		1000	6-8-4		B#
2		"	6-8-8		"
3		"	6-8-12		"
4		"	6-8-16		"
5		"	0-8-12		"
6		"	3-8-12		"
7		"	9-8-12		"
8		"	6-0-12		"
9		"	6-4-12		"
10		"	0-8-12		"
11		500	6-8-12		"
12		1500	6-8-12		"
13		1000	6-8-12	1000	"
14		"	6-8-12		"
15		"	0-8-12		"
16		500	6-8-12		R##
17		1000	6-8-12		"
18		1500	6-8-12		"
19		****	*****		***
20		1000	0-8-12		B
21	10	500	0-8-12		"
22	10	1000	3-8-12		"
23	10	"	3-8-8		"
24	10	500	3-8-12		"
25		1000	0-8-12		"
26	10	"	3-8-12		"
27	10	****	*****		***
28	20	****	*****		***
29		****	*****		***
30		1000	0-8-12		B
31		"	6-8-12		"

B Broadcast Application
R Row Application

Table II

The field treatments of the sulfur plots, tiers A, B, and C. All figures are given on the basis of pounds per acre.

Plot Number	1	2	3	4	5	6
Tier Number						
A#	0	300	600	900	1200	1500
B##	0	300	600	900	1200	1500
C###	0	300	600	900	1200	1500

1000 pounds per acre of 6-8-12

1000 pounds per acre of 3-8-12

1000 pounds per acre of 9-8-6

B. Experimental

1. Methods

The pH of the soils was determined by means of the quinhydrone potentiometer. A ratio of 2:1 of soil to water was employed since this appears to give a more constant reading throughout the reaction tube.

The lime requirement was determined by the use of calcium acetate adjusted to a pH of 7.0 and titration with saturated calcium hydroxide using the quinhydrone potentiometer.

For the carbon or organic matter determination use was made of the Shellenberger method for the rapid analysis of organic matter in soils (20).^{*} A 0.5000 gram sample of the soil was treated with 0.4000 normal potassium dichromate and concentrated sulfuric acid and boiled for five minutes. The excess potassium dichromate was determined by titration with 0.2000 normal ferrous ammonium sulfate using barium diphenylamine sulfonate as the indicator. The organic matter was estimated from the carbon by multiplying the percentage of carbon by a factor of 2.00.

Use was made of the series of quick test methods developed by Dr. F. G. Merkle (15) of the Department of Agronomy at The Pennsylvania State College, in the

^{*} As modified by I. V. Tiurin (26)

determination of the readily available nitrogen, phosphoric acid, potassium, and calcium.

2. Presentation of data

As mentioned before, seven determinations were made on each soil sample; namely, pH, lime requirement, organic matter, nitrogen, phosphoric acid, potassium, and calcium. The last four were determined by means of quick chemical tests. The results obtained are presented as follows:

Tables III and IV show the results from the three-year rotation plots for certain intervals during the 1936 and 1937 growing seasons. The lime requirements are given in the number of pounds of calcium carbonate required to neutralize the theoretical acidity of an acre six inches of soil. The nitrogen, phosphoric acid, potassium and calcium are given in pounds per acre. Tables V and VI present the same data for the same intervals and years from the sulfur plots. Samples C-1 and C-6 for June, 1937, from the sulfur plots are not given because of contamination of the soils during their preparation for analysis.

The samples from the outlying plots, upon analysis, resulted in the data presented in Table VII. The forty-four samples were taken between August 22, 1936, and August 25, 1936. The data is presented in the same manner as in Tables III and IV.

Table VIII gives the results obtained from the soils in the nitrogen carrier experiments. The four samples from each separate farm have been kept together in order to facilitate comparison of the results from the different carriers.

Figure I presents graphically the means of the readily available nitrogen, phosphoric acid, potassium, and calcium content from the three-year rotation plots for the different intervals during the 1936 and 1937 growing seasons. It must be kept in mind that the 1936 results were obtained from Tier II while the 1937 samples were taken from Tier III.

Figure II presents graphically the means of the readily available nitrogen, phosphoric acid, potassium, and calcium content of the sulfur plots for the different intervals during the 1936 and 1937 growing seasons.

Table III

The pH, lime requirement, and percentage of organic matter content of the three-year rotation plots at different intervals during the 1936 and 1937 growing seasons.

Plot Number	pH			Lime Requirement lbs. CaCO ₃ /acre			Organic Matter Per cent		
	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937
1	7.58	7.45	7.21	21	41	83	2.78	2.26	2.34
2	7.37	7.00	7.12	97	41	83	2.82	2.40	2.26
3	7.41	7.53	7.50	181	83	41	3.10	2.20	2.28
4	7.25	7.30	7.30	340	83	186	2.86	2.48	2.56
5	7.14	7.25	7.30	479	165	227	2.94	2.34	2.40
6	6.96	6.96	7.30	493	537	124	2.92	2.32	2.32
7	7.07	7.20	7.28	1427	392	124	2.70	2.38	2.44
8	7.03	7.41	7.27	1345	330	227	2.98	2.32	2.30
9	6.85	7.41	7.15	1596	805	165	2.98	2.50	2.36
10	7.07	7.60	7.15	691	372	103	3.24	2.40	2.30
11	7.21	7.55	7.35	398	496	83	2.82	2.50	2.44
12	7.18	7.54	6.93	733	764	248	2.76	2.32	2.52
13	7.09	7.46	7.21	377	1115	186	2.54	2.50	2.44
14	7.09	7.42	7.12	838	909	392	2.40	2.42	2.30
15	7.28	7.54	7.12	494	681	165	2.62	2.34	2.34
16	7.46	7.40	7.35	0	227	21	2.72	2.46	2.40
17	7.38	7.46	7.09	461	62	41	2.84	2.50	2.44
18	7.21	7.41	7.26	595	248	0	2.62	2.52	2.38
19	7.38	7.40	7.62	260	0	0	2.68	2.30	2.22
20	7.41	7.56	7.55	293	248	62	2.94	2.42	2.42
21	6.99	7.36	7.34	210	165	41	2.58	2.34	2.44
22	7.25	7.56	7.27	545	475	103	2.94	2.70	2.66
23	7.11	7.31	7.25	817	723	227	2.88	2.50	2.60
24	7.04	7.40	7.07	796	909	124	2.80	2.62	2.78
25	7.15	7.20	6.95	398	413	103	2.68	2.74	2.72
26	7.19	7.52	7.40	377	248	41	2.66	2.76	2.76
27	7.55	7.30	7.54	210	227	83	2.82	2.84	2.70
28	7.52	7.30	7.41	293	227	62	2.96	2.82	2.84
29	7.55	7.21	7.13	231	268	41	2.80	2.74	2.82
30	7.04	6.96	7.48	650	496	21	2.82	2.94	2.76
31	7.00	6.47	7.31	600	372	21	2.84	3.26	3.06

Table IV

The readily available nitrogen, phosphoric acid, potassium, and calcium content of the three-year rotation plots at intervals during the 1936 and 1937 growing seasons

Plot Number	Nitrogen Pounds per Acre			Phosphoric Acid Pounds per Acre			Potassium Pounds per Acre			Calcium Pounds per acre		
	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937
1	250	50	200	2.50	50.00	20.00	300	150	100	4000	3000	1200
2	200	100	200	10.00	5.00	2.50	300	100	100	3000	3000	2000
3	400	50	150	10.00	2.50	5.00	350	150	50	3000	2000	3000
4	250	50	150	5.00	10.00	5.00	300	200	200	2000	2000	3000
5	200	50	150	20.00	2.50	2.50	350	150	100	2000	2000	1200
6	300	50	200	20.00	20.00	2.50	350	150	150	2000	4000	3000
7	350	50	250	5.00	30.00	30.00	350	150	100	2000	3000	2000
8	250	50	200	10.00	25.00	30.00	350	200	100	1200	3000	3000
9	200	100	200	20.00	10.00	2.50	350	250	150	2000	4000	2000
10	150	100	150	10.00	10.00	5.00	350	200	200	2000	5000	2000
11	100	50	200	5.00	10.00	20.00	250	200	100	2000	5000	2000
12	150	0	200	5.00	15.00	5.00	350	100	250	1200	4000	2000
13	200	50	200	5.00	2.50	10.00	300	100	250	3000	800	3000
14	300	0	200	2.50	15.00	2.50	350	150	150	2000	800	3000
15	350	50	150	2.50	5.00	5.00	250	100	150	2500	2000	3000
16	300	50	200	10.00	25.00	5.00	300	100	100	2000	4000	4000
17	350	100	250	5.00	20.00	15.00	250	100	250	3000	4000	4000
18	250	50	200	5.00	20.00	5.00	250	150	300	2500	5000	4000
19	300	100	100	20.00	5.00	5.00	350	150	50	3500	6000	3000
20	300	50	150	5.00	20.00	5.00	200	200	100	300	1200	2000
21	350	0	200	2.50	10.00	2.50	300	100	100	2500	3000	3000
22	350	50	200	5.00	20.00	10.00	300	300	250	3000	1200	2000
23	300	50	200	2.50	20.00	2.50	350	200	150	2000	800	2000
24	300	100	200	2.50	5.00	10.00	200	200	100	2000	2000	2000
25	350	50	200	2.50	5.00	20.00	250	200	150	2000	5000	3000
26	350	250	150	2.50	5.00	10.00	200	250	150	3000	4000	4000
27	350	100	200	5.00	20.00	5.00	300	250	150	3000	5000	4000
28	350	100	200	5.00	5.00	50.00	300	300	250	4000	3000	3000
29	300	100	200	5.00	10.00	20.00	350	100	100	4000	3000	1200
30	300	100	200	2.50	10.00	30.00	300	100	150	2000	4000	3000
31	150	150	250	10.00	20.00	15.00	350	200	200	2000	5000	3000
Ave.	286	69	195	7.18	13.95	11.53	303	169	148	2497	3220	2639

Table V

The pH, lime requirement, and percentage of organic matter of the sulfur plots at intervals during the 1936 and 1937 growing seasons.

Number	pH			Lime Requirement lbs. CaCO ₃ /acre			Organic Matter Per cent		
	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937
1	5.35	6.96	5.93	3285	1941	2437	3.00	2.66	2.80
2	5.25	6.06	5.86	3428	2561	2602	2.82	2.86	3.04
3	5.59	6.01	5.76	3947	2912	3428	3.20	2.86	3.00
4	6.50	5.58	5.32	1058	3387	4086	3.08	3.86	3.04
5.	5.19	5.68	5.48	3719	3676	3882	2.84	3.14	3.22
6	5.01	5.37	5.24	4991	3428	3800	2.96	2.62	2.80
7	5.57	5.46	5.93	3128	2953	2891	2.90	2.34	2.42
8	5.85	5.75	5.94	2624	2685	2354	2.76	2.22	2.38
9	5.24	5.42	7.05	3436	2015	558	2.56	2.32	2.30
10	5.33	6.34	5.38	3725	3469	3304	3.12	2.40	2.70
11	5.08	5.75	5.38	4012	3387	3531	3.08	2.64	2.54
12	4.98	5.45	5.08	4017	3903	4465	2.74	2.46	2.48
13	6.18	-----	5.84	1993	-----	2936	3.26	-----	2.52
14	5.82	5.85	5.82	2292	3180	2602	3.58	2.46	2.30
15	5.76	5.73	5.51	2807	3387	3676	3.30	2.52	2.42
16	5.66	6.40	6.12	2950	1156	2106	3.46	2.34	2.48
17	5.57	5.58	5.30	3367	3552	3924	3.50	2.40	2.54
18	5.23	-----	4.93	3444	-----	4708	3.02	-----	2.30

Table VI

The readily available nitrogen, phosphoric acid, potassium and calcium content of the sulfur plots at intervals during the 1936 and 1937 growing seasons.

Plot Number	Nitrogen Pounds per Acre			Phosphoric Acid Pounds per Acre			Potassium Pounds per Acre			Calcium Pounds per Acre		
	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937	Aug. 1936	June 1937	Aug. 1937
A-1	200	50	150	2.50	2.50	10.00	250	350	250	1500	2000	1500
A-2	250	50	200	5.00	2.50	2.50	300	350	300	1000	1000	1000
A-3	300	50	150	2.50	2.50	2.50	350	300	350	1500	600	600
A-4	250	100	150	7.50	2.50	2.50	350	300	200	2000	1000	1000
A-5	400	50	150	2.50	2.50	2.50	300	350	250	600	400	600
A-6	300	100	100	5.00	5.00	10.00	300	350	200	400	400	1500
B-1	250	50	50	2.50	2.50	5.00	350	300	200	400	1500	1000
B-2	150	100	50	7.50	2.50	5.00	350	150	300	600	600	600
B-3	180	100	150	5.00	2.50	5.00	250	200	100	1000	600	2000
B-4	150	150	100	2.50	5.00	2.50	300	200	200	400	400	600
B-5	200	100	100	2.50	5.00	2.50	380	150	150	500	400	400
B-6	150	200	150	2.50	5.00	5.00	400	150	100	400	400	1000
C-1	250	---	100	10.00	---	5.00	400	---	200	1500	---	1000
C-2	300	50	150	10.00	2.50	2.50	350	100	200	1500	1500	1000
C-3	180	100	250	5.00	2.50	2.50	350	150	150	300	1500	1000
C-4	200	200	150	7.50	20.00	5.00	350	150	250	400	2000	1500
C-5	200	50	200	2.50	2.50	2.50	300	100	150	1500	1000	1000
C-6	200	---	150	2.50	---	2.50	300	---	150	1000	---	600
Ave.	228	94	139	4.72	4.22	3.61	346	228	206	900	956	994

Table VII

Results of analysis by "quick tests" for the outlying plots. Samples taken August 22-25, 1936.

Sample Number	Lime Requirement #	pH	Organic Matter Per cent	N ##	P ₂ O ₅ ##	K ##	Ca ##
19	920	6.60	2.44	200	30.00	150	2000
20	590	6.60	2.40	150	20.00	150	2500
21	4250	5.78	3.34	80	5.00	200	1500
22	4300	5.52	3.36	150	5.00	200	1000
23	1230	6.79	2.54	200	10.00	200	1000
24	1370	6.92	2.66	150	20.00	200	1000
25	2790	6.55	3.58	100	20.00	150	2500
26	2510	6.12	3.20	150	10.00	250	2500
27	274	7.14	2.44	200	100.00	300	3000
28	183	7.42	2.34	150	50.00	400	3500
29	2330	6.20	2.56	150	10.00	250	1500
30	2280	6.24	2.48	150	10.00	200	1500
31	3880	5.90	2.92	50	10.00	250	600
32	2980	6.12	2.46	50	20.00	200	1500
33	3300	5.78	1.74	10	10.00	400	400
34	3110	5.58	1.70	10	2.50	250	600
35	4060	5.93	2.24	10	10.00	300	1000
36	3110	5.88	2.82	100	10.00	250	1500
37	1780	6.52	1.88	150	10.00	150	1500
38	3660	6.55	1.96	80	5.00	100	1000
39	1140	6.67	2.30	150	20.00	250	2000
40	960	6.67	2.06	100	10.00	200	1000
41	3020	6.19	3.50	150	10.00	200	1500
42	2740	6.11	3.92	150	20.00	300	2000
74	1116	6.94	3.00	100	50.00	350	3000
75	4257	5.83	2.86	250	3.75	200	400
76	3092	6.00	2.92	200	15.00	100	800
77	1860	6.99	1.96	50	3.75	100	2000
78	1073	7.09	1.94	150	5.00	100	3000
79	325	7.43	2.60	50	4.50	200	2000
80	679	7.18	2.70	150	7.50	100	3000
81	1257	6.99	2.38	100	1.00	200	3000
82	1257	6.54	2.48	100	2.50	300	1200
83	1286	6.96	2.50	200	2.50	300	1200
84	4517	5.63	3.38	250	10.00	350	800
85	4136	5.73	2.52	150	30.00	250	1200
86	2032	6.55	4.10	200	2.50	400	3000
87	1969	6.72	2.24	50	2.50	100	2000
88	1207	7.12	3.00	100	5.00	150	2000
89	0	7.24	2.98	100	10.00	300	2000
90	1362	6.96	2.34	250	5.00	300	3000
91	2355	6.75	2.34	150	10.00	200	2000
92	2840	6.21	2.72	150	5.00	250	3000
93	3390	5.98	1.88	100	10.00	150	400

Pounds per Acre

Pounds CaCO₃ per Acre

Table VIII

Results of Analysis by Quick Tests for the Outlying
Experimental Fertilizer Plots.

Sample Number	pH	Lime Require- ment ##	Organic Matter Per cent	N #	P ₂ O ₅ #	K #	Ca #
500	6.30	2788	2.92	150	5.00	200	1500
601	5.82	2808	2.80	200	20.00	200	1000
602	5.82	2746	2.40	150	5.00	200	2000
603	5.78	2808	2.50	150	10.00	150	1500
501	6.27	2230	2.36	150	5.00	200	1500
604	5.46	2404	2.30	150	10.00	100	2000
605	6.10	2181	2.24	200	10.00	250	2000
606	6.10	1404	2.50	50	20.00	200	2000
502	6.10	2272	2.44	100	5.00	150	600
607	5.81	2181	4.22	150	10.00	150	1000
608	5.70	2156	2.32	100	10.00	150	1500
609	6.22	2024	2.66	50	20.00	150	1500
503	5.66	3221	2.10	150	10.00	100	600
610	5.50	2156	2.22	250	5.00	300	1500
611	5.57	2637	2.28	200	5.00	300	2000
612	5.57	2651	2.30	200	5.00	300	2000
504	5.85	2994	2.18	100	5.00	250	1000
613	6.10	1718	2.30	200	10.00	350	2000
614	5.81	2519	2.66	200	10.00	300	2000
615	5.94	1797	2.58	100	10.00	350	2000
505	5.70	3304	3.16	150	10.00	250	2000
616	5.64	3254	2.36	50	5.00	250	1000
617	5.67	3147	2.82	100	10.00	250	1000
618	5.67	2561	2.58	150	10.00	250	2000
506	6.32	1673	2.54	50	10.00	400	2000
619	6.19	1239	2.50	50	100.00	400	2000
620	6.33	1363	2.52	150	100.00	400	2000
621	6.21	1446	2.50	200	100.00	350	2000
507	5.67	3345	3.74	250	5.00	300	2000
622	6.62	1260	3.50	50	20.00	350	2500
623	6.55	1322	3.42	150	20.00	300	2500
624	6.32	1673	3.78	100	30.00	300	3000
506	6.11	1755	2.38	200	10.00	350	1500
625	6.25	1859	3.84	100	10.00	250	2000
626	6.17	2024	2.60	100	20.00	300	2000
627	6.05	2127	2.70	50	10.00	250	2000

Pounds CaCO₃ per Acre

Pounds per Acre

Figure I

The relationship of the sampling date to the means of the readily available nitrogen, phosphoric acid, potassium, and calcium content of the three-year rotation plots.

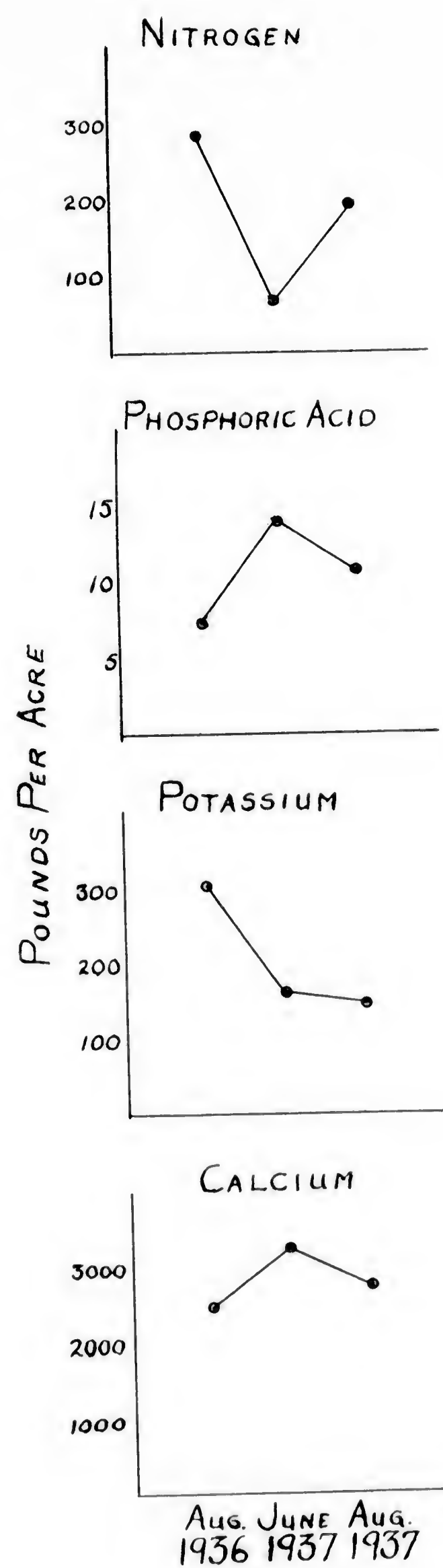
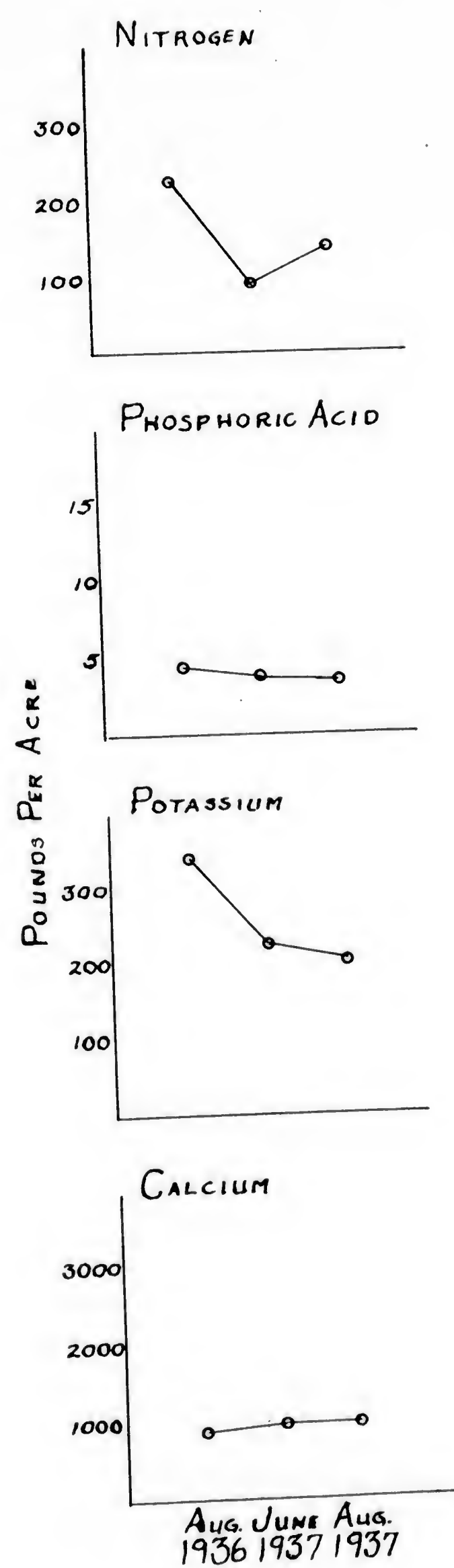


Figure II

The relationship of the sampling date to the means of the readily available nitrogen, phosphoric acid, potassium, and calcium content of the sulfur plots.



3. Discussion of results

The results of the pH determinations indicate that the average Lancaster County tobacco soil lies within the range of pH 5.50 to 7.20. Several of the three-year rotation plots have higher pH values than this but they are exceptions due to fertilizer treatment.

The lime requirement, as determined in this manner, tends to follow the pH of the soils. However, even though the soil is on the alkaline side of pH 7.00, it is possible to have replaceable hydrogen. Therefore, certain of the samples having pH values higher than seven show lime requirement.

The organic matter, as determined by the rapid test used, varies from 1.50 to 4.00 per cent. Little or no correlation can be obtained between this value and any other of the values studied.

Readily available nitrogen tends to be comparatively high at the end of the two growing seasons and lower at the beginning of the season. The tobacco grown on the experimental fields in 1937 had thin leaves having little or no body. The nitrogen should be higher at the beginning of the season when the plant is growing more rapidly in order to obtain leaves of good market value.

The available nitrogen was lower at the end of the

1937 season than at the end of the 1936 season. This was true because the 1937 season was very wet, more leaching of soluble salts took place, giving lower nitrogen values. During a year of normal rainfall it would hardly be necessary to add much nitrogen in the fertilizer. A small amount would probably be necessary in order to have enough present to start the growth of the plant.

Phosphoric acid, in Lancaster County soils, remains fairly constant over a period of one year, even one with heavy rainfall. However, in almost all cases the quantity is lower than the amount required by the tobacco plant. The tendency is for loss during the growing season. The ratio of nitrogen to potassium is too high. Therefore, it would be in order to increase the potassium content slightly to give tobacco having good body and above average burn.

The calcium content of most of these soils is somewhat too high. For tobacco, a pH of 6.20 to 6.40 is advisable. Therefore, a decrease in calcium is usually necessary.

In acid soils, a decrease in phosphoric acid can be noted with increased calcium content. However, in neutral and alkaline soils this tendency is not evident. In fact, the analyses show the inverse to be true. More work is in progress from which it is hoped to obtain

positive proof or disproof of this observation.

Little or no differences can be noted in the effect of additions of different nitrogen carriers. In all cases except two the available calcium increased. In these two cases little change can be noted in the pH. If this experiment was carried on for many years perhaps the treatment would show an over-shadowing of the inherent fertility of the soils studied and differences could be noted.

The results depicted in Figure I for the three-year rotation plots may be identical with those of the sulfur plots, Figure II, since the 1936 and 1937 samples were taken from different tiers. Even though the tiers have had the same treatments the inherent fertility of these plots may spoil the comparison. The general trend of the available constituents determined, except calcium, is in the same general direction for the 1937 growing season. The difference in the calcium may be due to the sulfur treatments. As the season progresses, small amounts of insoluble calcium may be liberated from the sulfur plots. However, in the three-year rotation soils, there is a high available calcium content and leaching progresses during the year to decrease this quantity.

Summary

Under the conditions of this experiment, the following conclusions appear to be justified:

1. The pH range of the Lancaster County soils, according to the data presented, is approximately from 5.50 to 7.20.
2. The potentiometric determination of lime requirement follows the pH of the soil to a large extent.
3. Available nitrogen increases during the summer months.
4. Years of heavy rainfall give lower quantities of available nitrogen at the end of the growing season.
5. The readily available phosphoric acid content of the soils, while below the minimal requirements of the tobacco plant, remains fairly constant over a period of one year.
6. The potassium availability decreases somewhat during a growing season and should be built up so that the N:K ratio is smaller.
7. In acid soils, increased calcium availability leads to decreased phosphoric acid availability. In neutral or alkaline soils the converse is indicated.
8. Additions of different nitrogen carriers shows

little or no effect on the availabilities of the several plant nutrients studied.

9. A system of fertilizer recommendations should be tabled until more experimental evidence on results of recommendations to date have been made available.

Appendix

Explanation of sample numbers.

Samples numbered 19 to 42 inclusive and 74 to 93 inclusive were taken in August 1936 from farms well distributed over the county. The names of the farms and the corresponding sample numbers are given in Table A.

Table A

Sample Number	Farm	Sample Number	Farm
19	Espensshade-A	41	Paul Newswenger-A
20	Espensshade-B	42	Paul Newswenger-B
21	Willis Landis-A	74	H.B. & S.N. Munma
22	Willis Landis-B	75	Raymond Kaufman #2
23	Daniel Smoker-A	76	Raymond Kaufman #1
24	Daniel Smoker-B	77	M. H. Musser
25	David Rutt-A	78	Elam S. Horst #1
26	David Rutt-B	79	Elam S. Horst #2
27	John Lefever-A	80	Henry M. Nolt
28	John Lefever-B	81	Jacob N. Martin
29	Martin Bare-A	82	Elmer Z. High
30	Martin Bare-B	83	Paul Z. Gehman
31	Charles Miller-A	84	C. S. Habecker #1
32	Charles Miller-B	85	C. S. Habecker #2
33	Levi Lefever-A	86	C. S. Habecker #3
34	Levi Lefever-B	87	C. S. Habecker #4
35	Aron H. Weaver-A	88	Roher Getz
36	Aron H. Weaver-B	89	Noah Getz
37	J. R. Barge-A	90	-----
38	J. R. Barge-B	91	D. E. Eby #1
39	Edwin Bare-A	92	D. E. Eby #2
40	Edwin Bare-B	93	D. E. Eby #3

The samples numbered 500 to 508 inclusive were taken June 2, 1937, from representative farms over the county as shown by Table B. After sampling, the above plots were divided into three equal plots and fertilized according to Table C. On September 3, 1937, samples were taken from each of these plots and numbered from 601 to 627 as indicated in Table D.

Table B

Sample Number	Farm	Sample Number	Farm
500	Charles Miller	505	Daniel Lennox
501	Chester Ranck	506	H. B. & S. N. Mumma
502	Edwin Bare	507	U. S. Delp
503	Aaron Weaver	508	Ben. Mellinger
504	Israel Mumma		

Table C

Fertilizer mixtures for the nitrogen carrier experimental plots

Plot Number	Fertilizer Mixture - Pounds of Constituent				
	Cottonhull Ashes	Nitrogen Carrier	Quantity	Steamed Bone Meal	KNO
A	1300 #	Cottonseed Meal	360 #	640 #	100 #
B	1300	Urea	52 ##	640	100
C	1300	Soybean Meal	360	640	100

2400 pounds per mixture; 600 pounds of mixture per acre.

300 pounds inert filler added to make total of 2400 pounds.

Table D

Sample Number	Farm	Sample Number	Farm
601	Charles Miller-A	615	Israel Mumma-C
602	Charles Miller-B	616	Daniel Lennox-A
603	Charles Miller-C	617	Daniel Lennox-B
604	Chester Ranck-A	618	Daniel Lennox-C
605	Chester Ranck-B	619	H. B. & S. N. Mumma
606	Chester Ranck-C	620	H. B. & S. N. Mumma
607	Edwin Bare-A	621	H. B. & S. N. Mumma
608	Edwin Bare-B	622	U. S. Delp-A
609	Edwin Bare-C	623	U. S. Delp-B
610	Aaron Weaver-A	624	U. S. Delp-C
611	Aaron Weaver-B	625	Ben. Mellinger-A
612	Aaron Weaver-C	626	Ben. Mellinger-B
613	Israel Mumma-A	627	Ben. Mellinger-C
614	Israel Mumma-B		

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